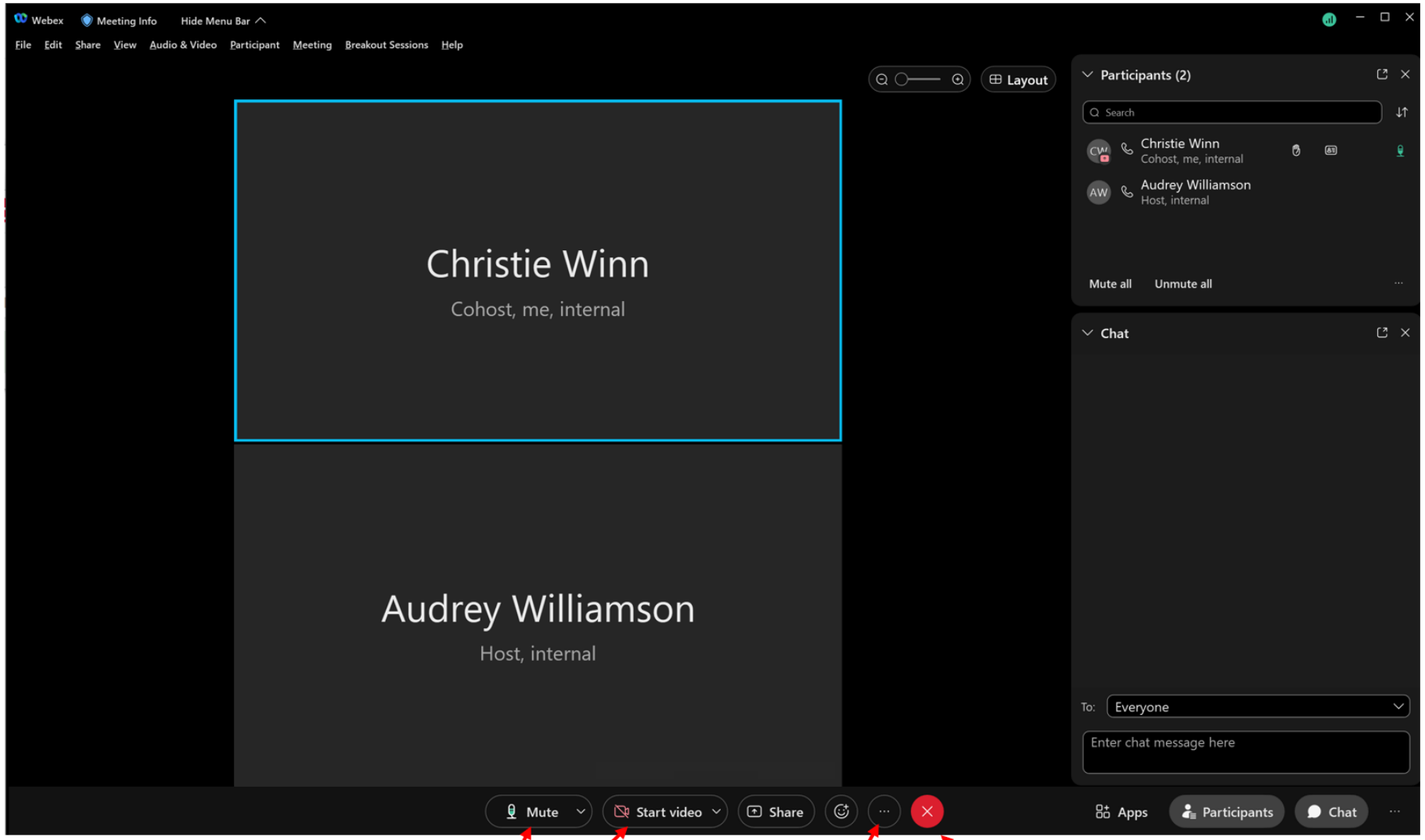


Please note, we are recording all sessions and ask that you stay muted and use the Chat function to ask questions during presentations. We have time set aside for Q&A after sessions to allow folks to come off mute.

Click the chat bubble to open the Chat box. Please be sure to select "Everyone" before sending your message.

Click here to mute or unmute yourself

Click here to start your video

If you experience any audio issues, please click here to switch audio connection. We recommend choosing "Call me" and connect with a phone/mobile device.

Click here to leave the meeting. We hope you choose to stay until the end.

Antitrust Guidelines

Antitrust Guidelines for EPRI Meetings and Conferences

The antitrust laws and other business laws apply to EPRI, its Members, participants, funders, and advisers; violations can lead to civil and criminal liability. EPRI is committed to both full compliance and maintaining the highest ethical standards in all of our operations and activities. These guidelines apply to all occasions: before, during, and after EPRI meetings, including in the hallways, over lunch, during breaks and at dinner.

EPRI'S PRIMARY PURPOSE

…is to conduct research and development relating to the generation, delivery and use of electricity for the benefit of the public. EPRI advisory meetings are conducted to further that purpose.

YOUR ROLE AT EPRI ADVISORY MEETINGS

…is to follow the meeting agenda and provide advice on EPRI's R&D program and how to make EPRI results most useful. Consult with your company counsel if at any time you believe discussions are touching on sensitive antitrust subjects such as pricing, bids, allocation of customers or territories, boycotts, tying arrangements and the like.

Antitrust Guidelines for EPRI Meetings and Conferences *(continued)*

DO NOT DISCUSS PROHIBITED TOPICS SUCH AS

…pricing, production capacity, or cost information which is not publicly available; confidential market strategies or business plans; or other competitively sensitive information. Do not disparage suppliers and/or competitors of EPRI, technology providers and/or EPRI Members and participants.

EPRI DOES NOT ENDORSE OR RECOMMEND

…the use of particular vendors, contractors or consultants for non-EPRI projects. EPRI will not promote or endorse commercial products or services of third parties. You must draw your own conclusions and make your own choices independently.

BE ACCURATE, OBJECTIVE, AND FACTUAL

…in any discussions of goods and services offered in the market by others, including your competitors, suppliers, and customers.

Antitrust Guidelines for EPRI Meetings and Conferences *(continued)*

DO NOT AGREE WITH OTHERS TO ENGAGE IN PROHIBITED ACTIVITIES SUCH AS

…to discriminate against or refuse to deal with (i.e., "boycott") a supplier; or to do business only on certain terms and conditions; or to set price, divide markets, or allocate customers.

DO NOT TRY TO INFLUENCE OTHERS TO ENGAGE IN ANTI-COMPETITIVE BEHAVIOR

…or advise others on their business decisions, and do not discuss yours (except to the extent that they are already public).

ASK

…for advice from your own legal department, if you have questions about any aspect of these guidelines or about a particular situation or activity at EPRI; or ask the responsible EPRI manager to contact EPRI's Legal Department.

Why are we here?

Flight Automation and Inspection Quality

EPRI Research and Industry Collaboration

Dexter Lewis, PE
Pr. Technical Leader
dlewis@epri.com

UAS Automation Technologies for Transmission Inspection *Phase 2*

Objectives and Scope

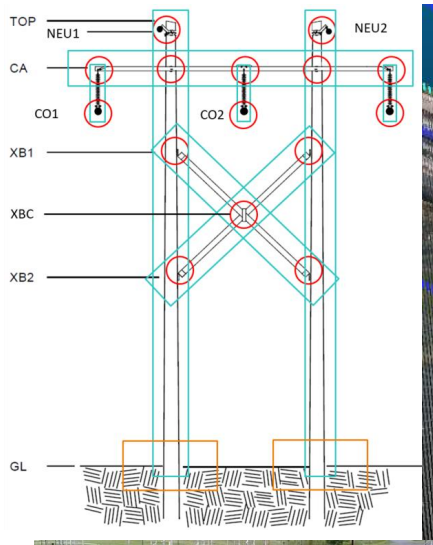
- Build on previous research to evaluate automated comprehensive transmission inspections using UAS
- Determine efficiency impact of using automation for inspection
- Compare inspection quality, speed, and cost to traditional methods

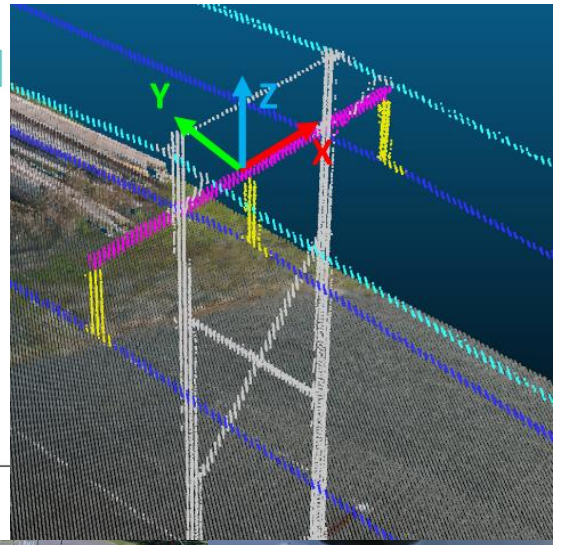
Value

- Knowledge to support implementation decisions
- Firsthand experience with an automated inspection solution
- Increased awareness of the near, mid, and long-term potential of UAS

Project Information

- Project ID: 1-112942
- Project Supplemental Number: 3002017783
- Project Manager: Dexter Lewis, dlewis@epri.com





Advanced Distribution Inspection:
Using Automation for Inspection

Objectives and Scope

- Guidance on technologies and approaches for automating distribution inspection
- Learn through lab and field experience how to collect the right inspection data
- Understand the feasibility of using automated image analysis for defect detection
- Quantify performance of AI predictions with objective processes and datasets

Value

- Experience with a new, automated inspection approach that may reduce the cost of distribution inspection
- Provide objective data to inform deployment decisions such as inspection processes, vendor selection, and purchasing decisions

Project Information

- Project ID: 1-113854
- Project Supplemental Number: 3002019622
- Project Manager: Dexter Lewis, dlewis@epri.com

Automation can reduce flight times for drone-based utility inspections.

Stoney Point Rd

Structure
Take-off Location

Inspector Route
Inspector Route

Without flight automation, inspectors commonly travel to every structure.

Duck Creek Rd

© 2020 Google

2067 ft

Google Earth

With automation, inspectors can fly multiple structures from one location.

© 2020 Google

2070 ft

Google Earth

Automation can help in those ‘tricky’ areas…even when you’re standing at the base of the pole/structure.

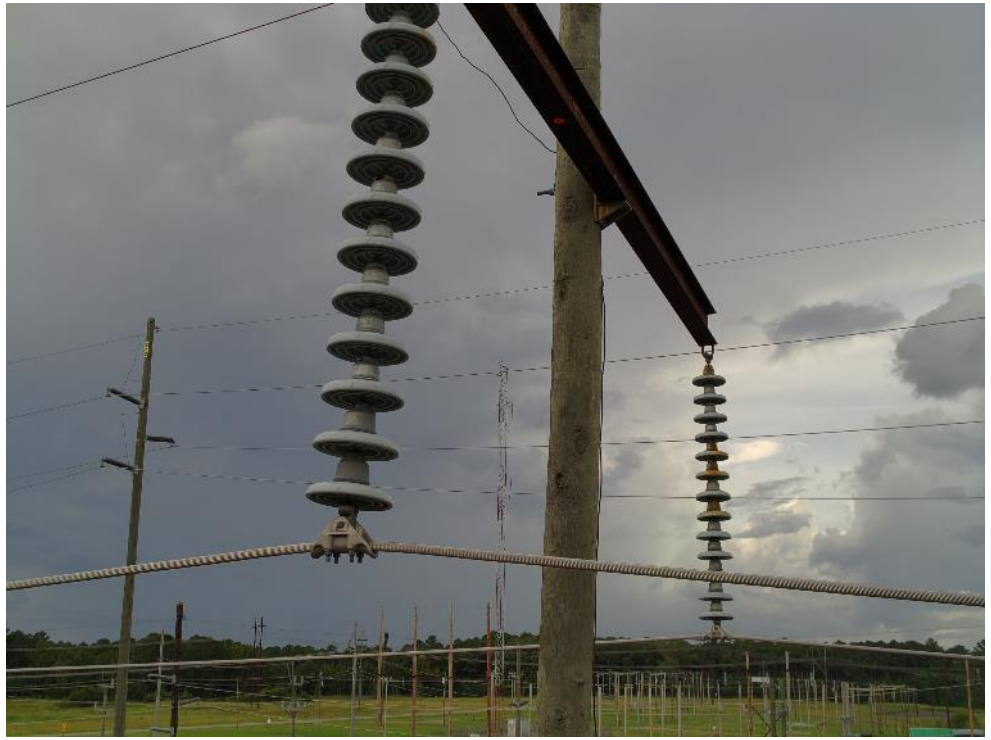
The inspection requirements determine the flight profile.

Aerial Patrols

- Quick “fly-by’s” looking for large and easily identifiable issues
- Fast, but limited perspective and resolution

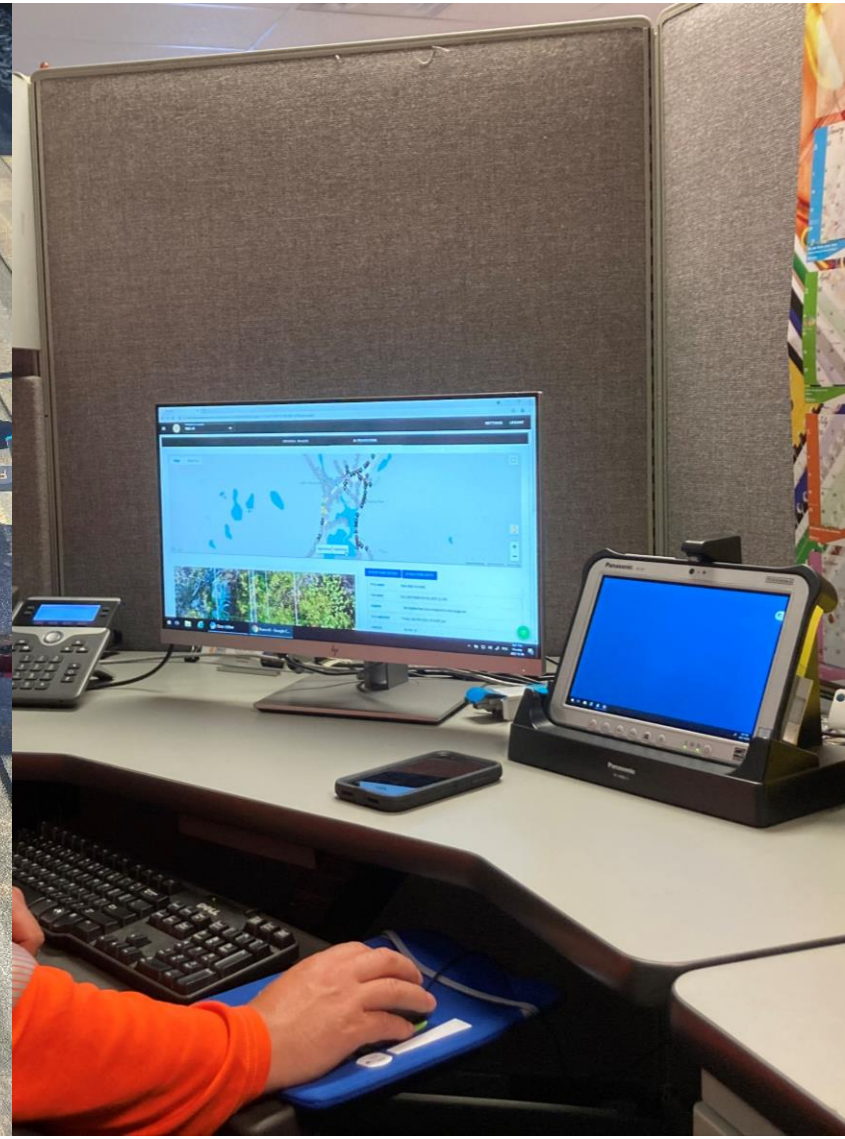
Comprehensive Inspections

- “Hovering” flights looking for component failures from multiple perspectives
- Slow, but multiple perspectives and higher resolution



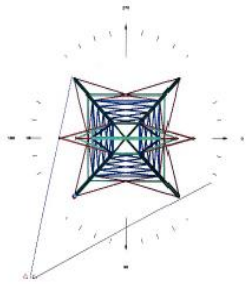
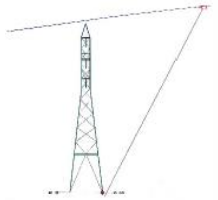
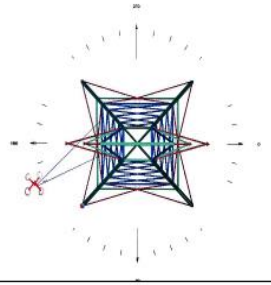
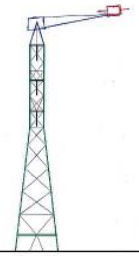
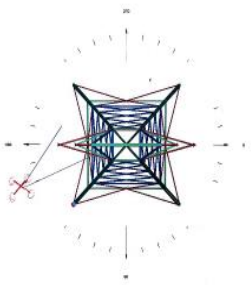
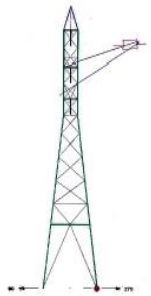
Inspection requirements should include image quality, resolving power, perspective, and field of view.

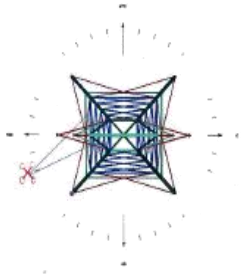
The inspection review can occur during or after the flight.

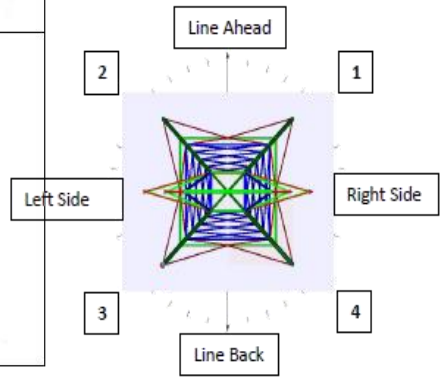


Shot-sheets can help humans perform better inspections.

Transmission - Live Inspection Shot Sheet

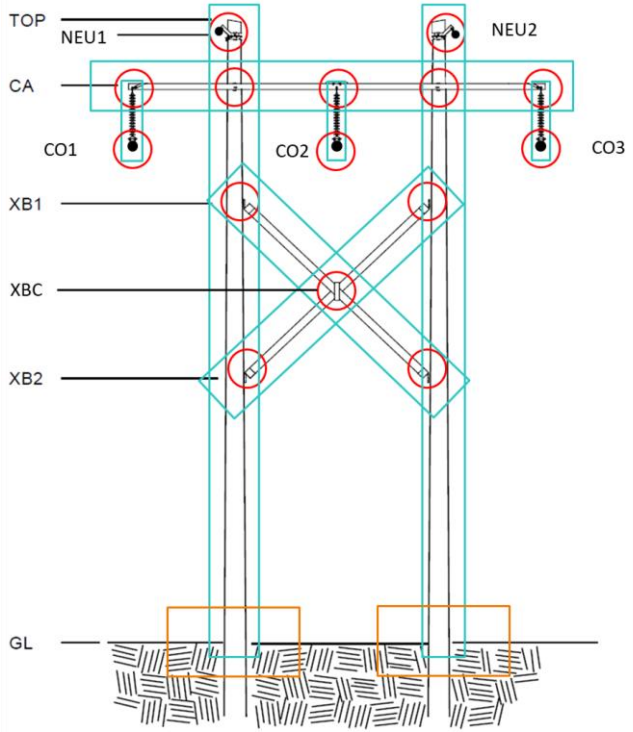
Shot #	Description	Example Photo	Plan View	Profile View
#1 – 45 High Oblique	Shot encompassing the entire structure from the shield wire to the structure base taken from a 45-degree angle with approximately a 45-degree camera tilt.			
#2 - Shield Wire (Two Positions)	Shot taken of the shield wire connection point from above the tower which shows the condition of the shield wire three feet each side of the connection point and the condition of the connection point itself.			
#3 – Look Down Insulator (Two Positions)	Shot of each phase's insulator string looking down on the insulator so that 90% of the insulator is visible (only 10% of the lower insulator being covered by the bell). Looking for insulator flashing, breaks, cracks.			

Insulator Connection Shots (Every Phase – Top & Bottom)	Tight Zoom shot of the top and bottom connection points of each insulator for each phase. Verifies cotter-key and structure integrity			
"AOC" – Area of Concern Shots	Additional shots as required to document areas of concern found during the live inspection. Examples of Areas of concerns documented further in this document.		AS REQUIRED	AS REQUIRED

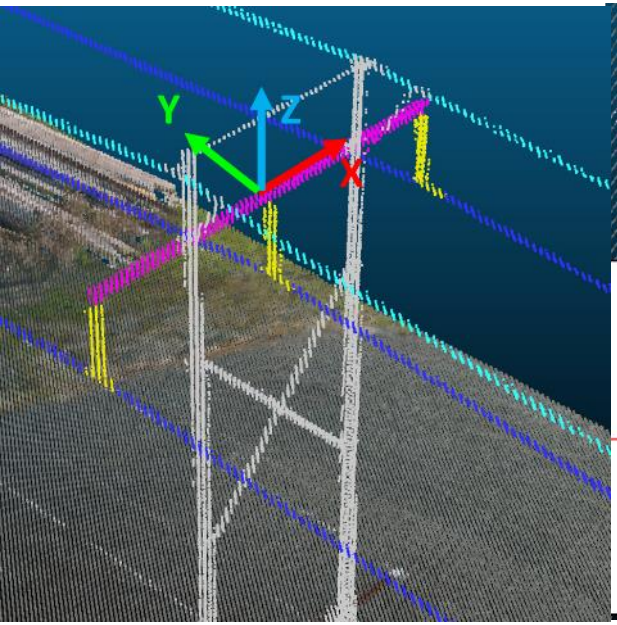


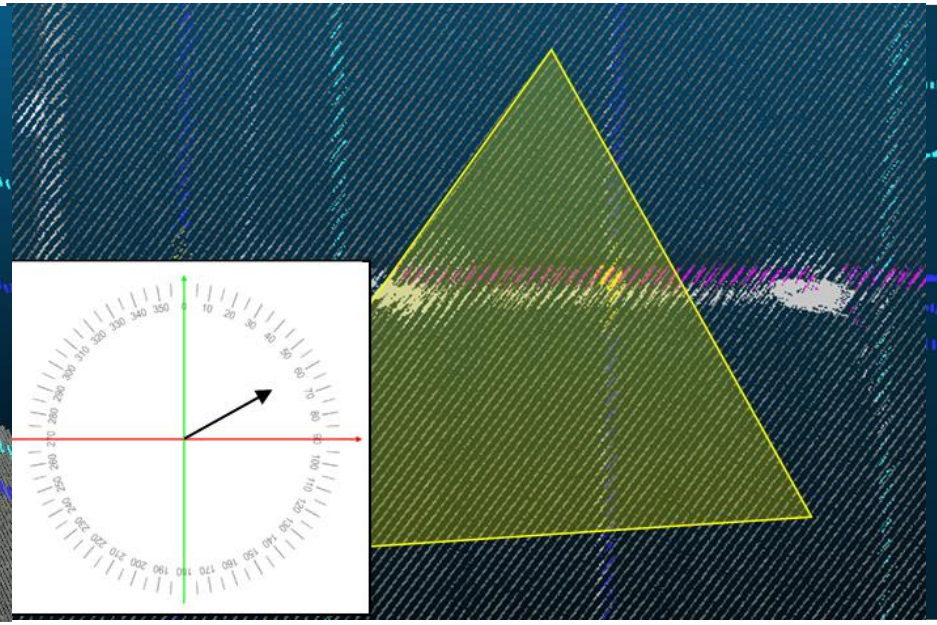
- Tower footing may be painted "White or Black" at the base to indicate a "White" or "Black" Circuit
- Structure Tags are traditionally placed on the structure below the lowest phase arms. Not all towers are standardized
- In addition to the shot sheet crews are required to inspect the entire tower and capture additional images or any Areas of Concern or "AOC's" found
- Standard flight profile is two complete a minimum of two positions from diagonally opposing sides. (3&1, 4&2). Standard profile is 3,1
- Profile should be chosen for best lighting due to sun angle
- Total photo count per structure for a Dual Circuit Lattice Tower should be approximately 30 pictures

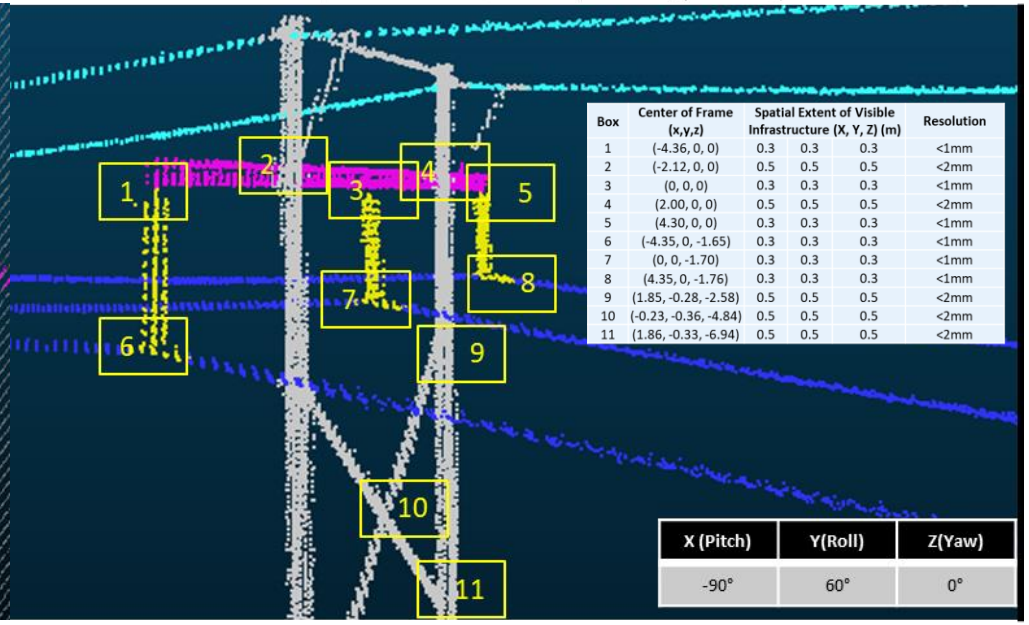
How do we create shot-sheets for machines?



Within the UAS Automation Phase 2 project, EPRI built and tested a workflow.





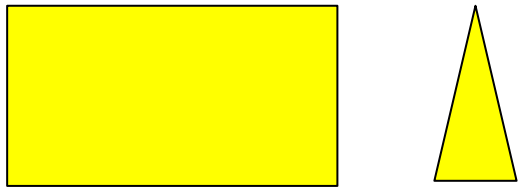


Box	Center of Frame (x,y,z)	Spatial Extent of Visible Infrastructure (X, Y, Z) (m)			Resolution
1	(-4.36, 0, 0)	0.3	0.3	0.3	<1mm
2	(-2.12, 0, 0)	0.5	0.5	0.5	<2mm
3	(0, 0, 0)	0.3	0.3	0.3	<1mm
4	(2.00, 0, 0)	0.5	0.5	0.5	<2mm
5	(4.30, 0, 0)	0.3	0.3	0.3	<1mm
6	(-4.35, 0, -1.65)	0.3	0.3	0.3	<1mm
7	(0, 0, -1.70)	0.3	0.3	0.3	<1mm
8	(4.35, 0, -1.76)	0.3	0.3	0.3	<1mm
9	(1.85, -0.28, -2.58)	0.5	0.5	0.5	<2mm
10	(-0.23, -0.36, -4.84)	0.5	0.5	0.5	<2mm
11	(1.86, -0.33, -6.94)	0.5	0.5	0.5	<2mm

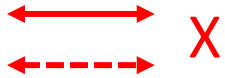
X (Pitch)	Y(Roll)	Z(Yaw)
-90°	60°	0°

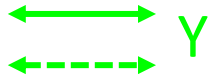
Notes

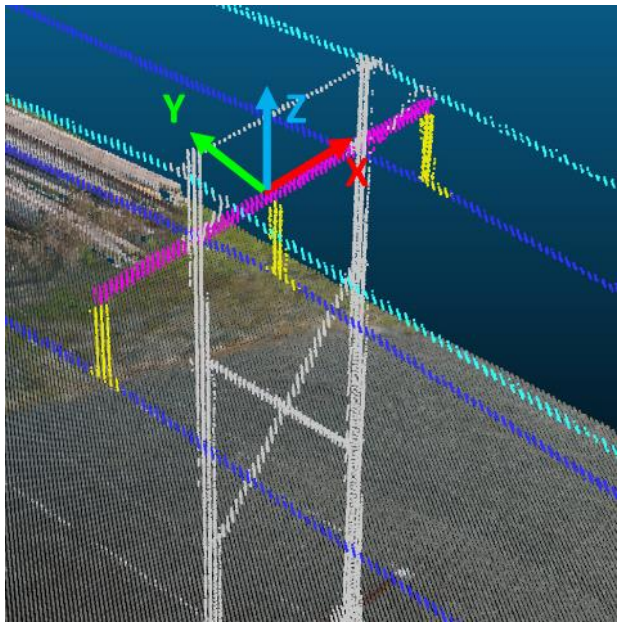
- Field of view overlays are not drawn to scale

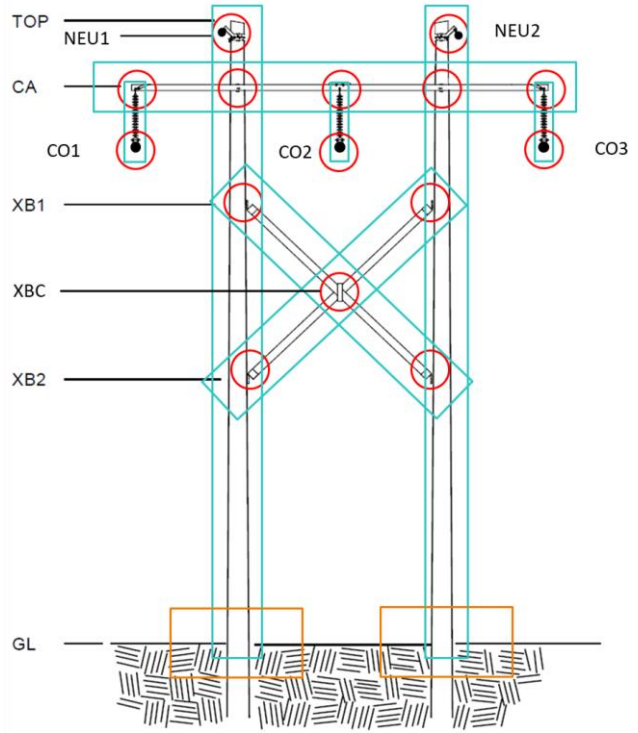


- Dimension arrows are not drawn to scale. However, the color indicates the axis.



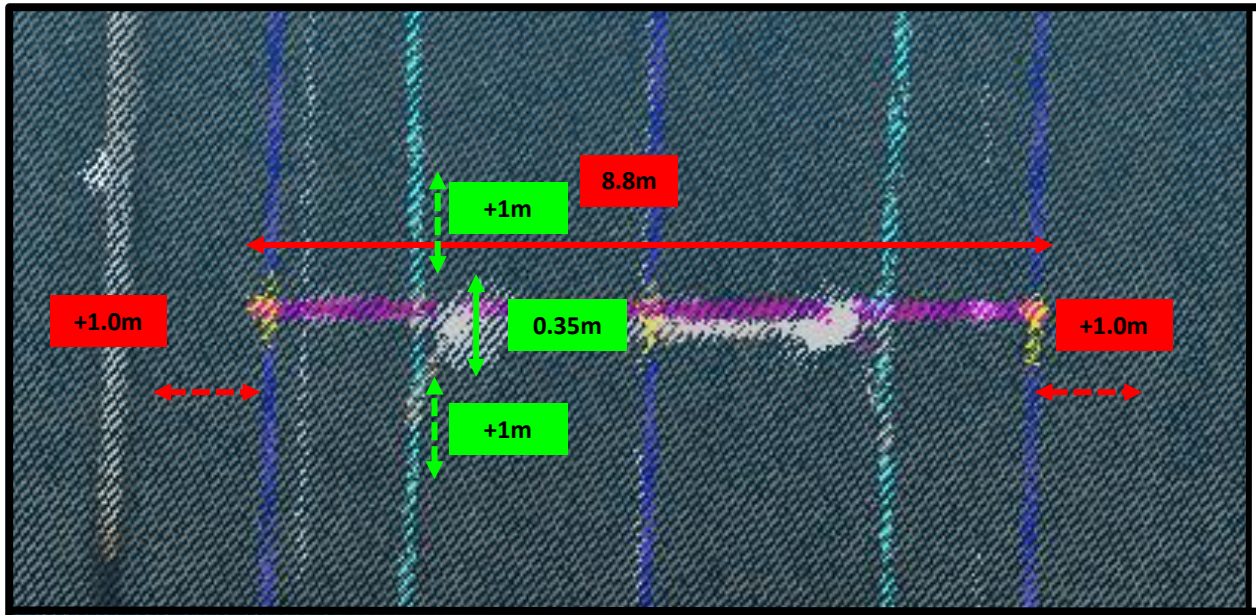




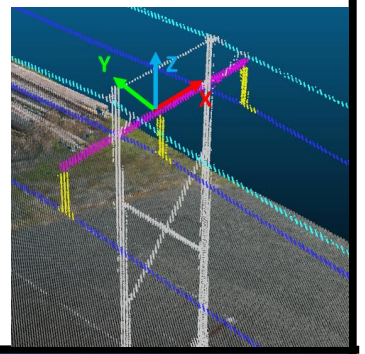


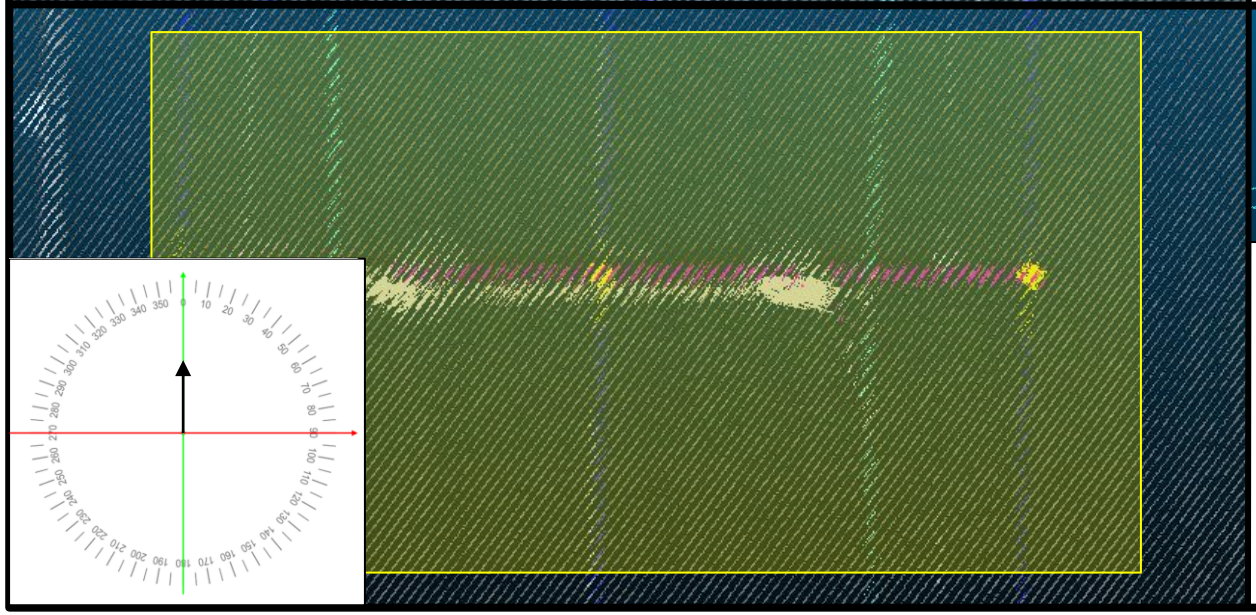
H-frame, L1 “Structure Overview, Centered, Nadir”

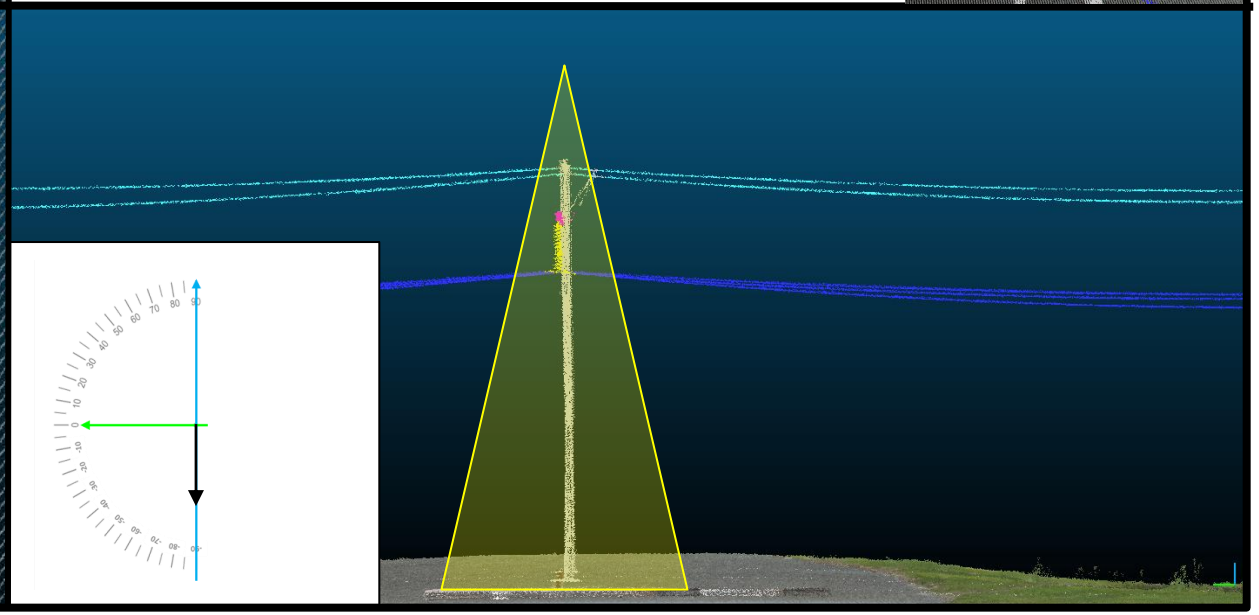
Collective Image Total: 1



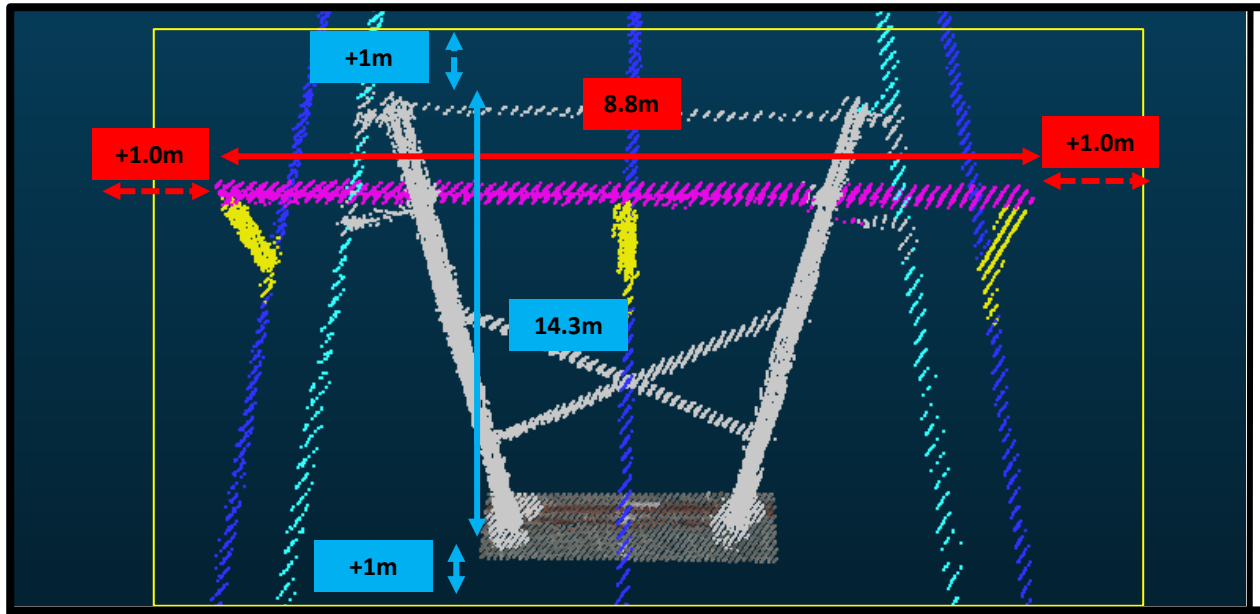
- (0,0,0) *(x, y, z) of center of image*
- 0° azimuth in XY plane *azimuth/yaw clockwise with respect to forward X axis)*
- -90° pitch YZ plane *Angle up/down from horizontal (elevation/pitch)*
- Spatial resolution undefined for structure overview *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical *What should be in focus in the field of view?*
  - >10.8m horizontal along X
  - >2.35m vertical along Y
- Verbal Description:
  - Directly above the structure. Looking down on the entire structure.
- Inspection Items
  - Objects: CA, PO1, PO2, CO1, CO2, CO3, NEU1, NEU2
  - Connection Points: NEU1_CP, NEU2_CP



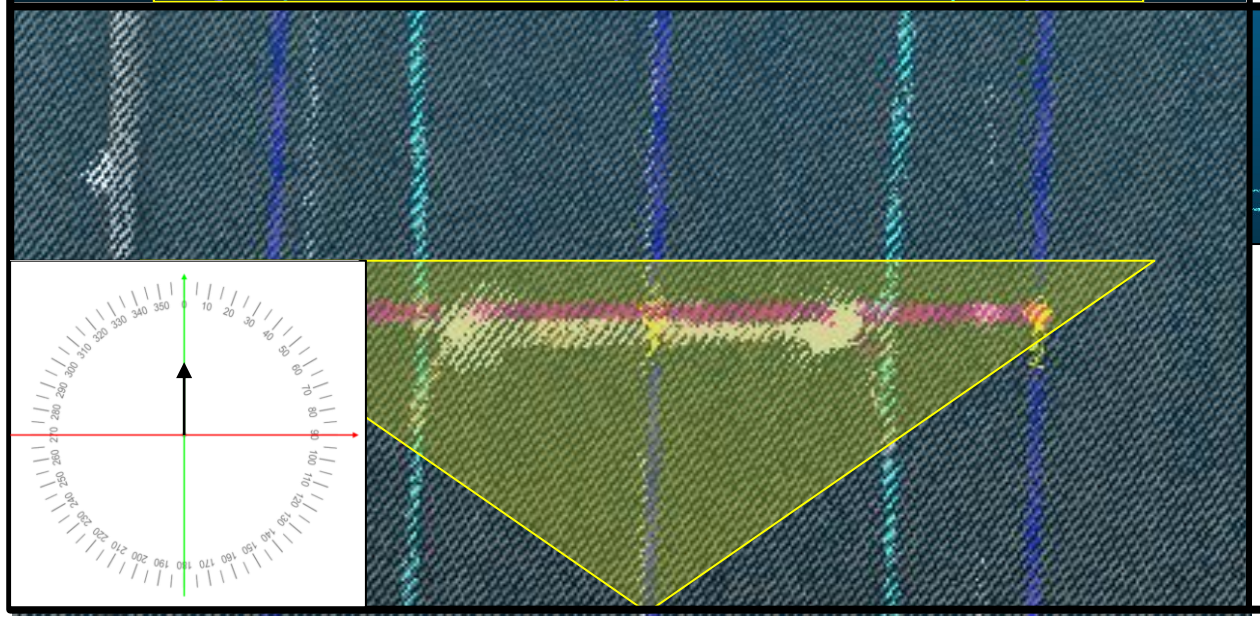


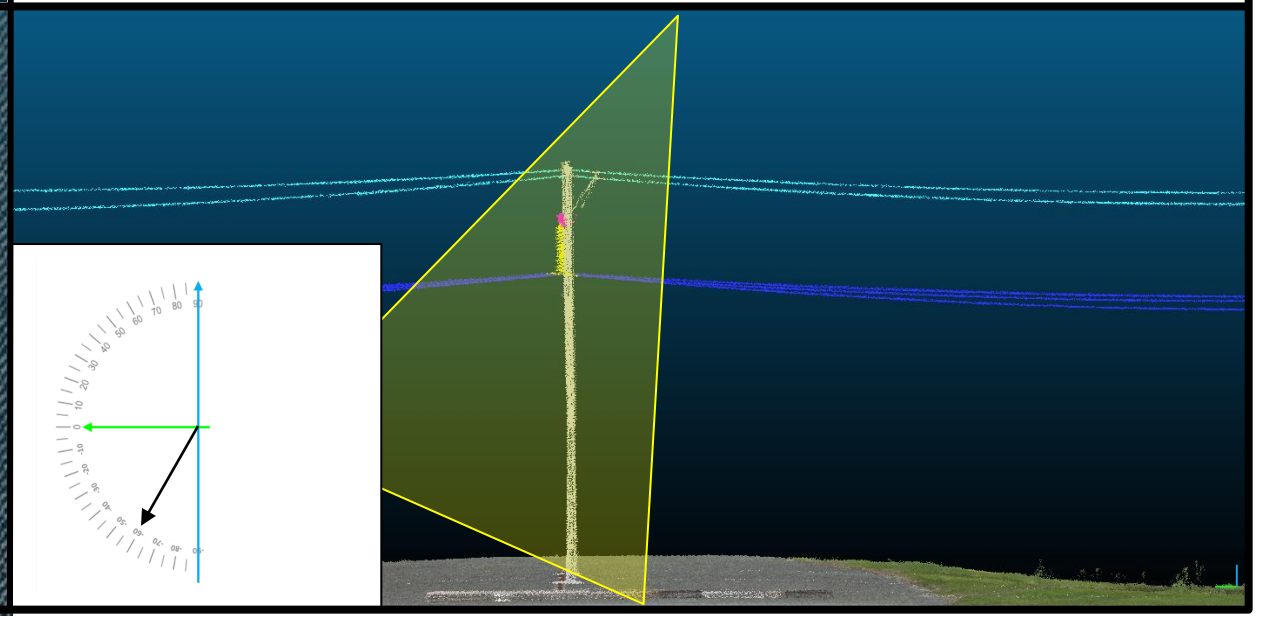


H-frame, L2A "Structure Overview, Center at mid-height, Oblique Forward" Collective Image Total: 2

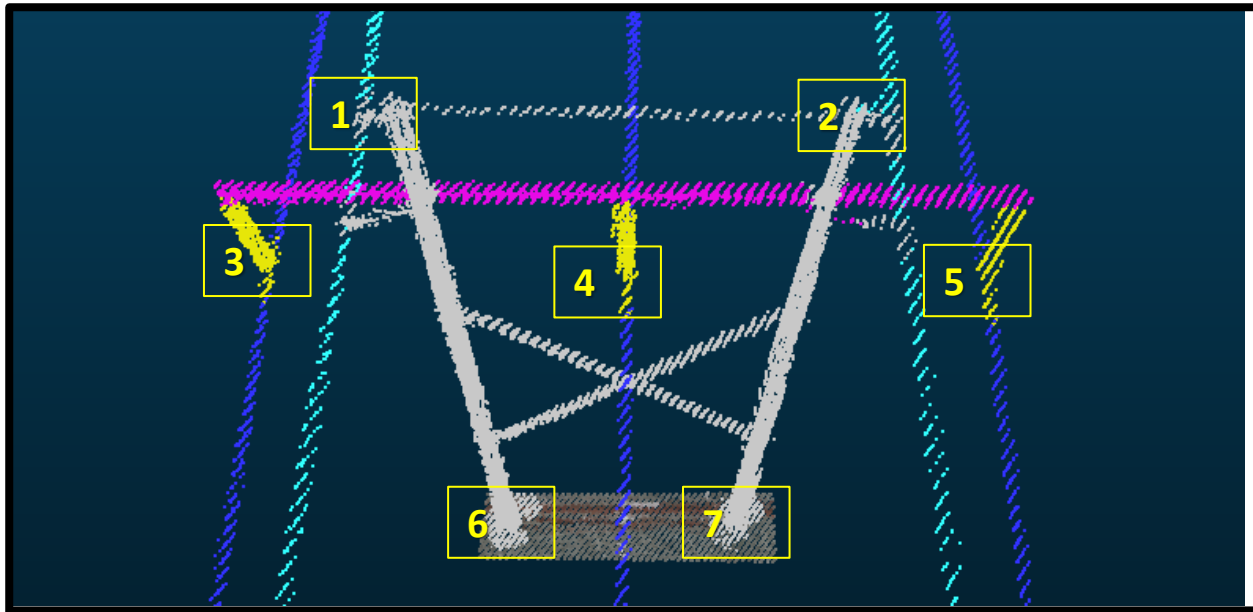


- (0,0,-5.1m) *(x, y, z) of center of image*
- 0° azimuth in XY plane *azimuth/yaw clockwise with respect to forward X axis)*
- -60° pitch YZ plane *Angle up/down from horizontal (elevation/pitch)*
- Spatial resolution undefined for structure overview *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical *What should be in focus in the field of view?*
  - >10.8m horizontal along X
  - >16.3m vertical along Z
- Verbal Description
  - Oblique offset, looking down on the structure with the entire structure in the frame (minus conductors)
- Inspection Items
  - Objects: CA, PO1, PO2, CO1, CO2, CO3, NEU1, NEU2, IN1, IN2, IN3, XB1, XB2, XBC, GL1, GL2
  - Connection Points: NEU1_CP, NEU2_CP, CO_CP1, CO_CP2, CO_CP3, XBC_CP1



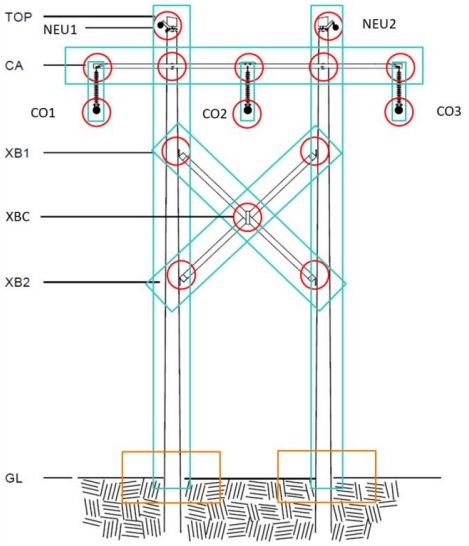


H-frame, L2A "Structure Overview, Center at mid-height, Oblique Forward" Collective Image Total: 9



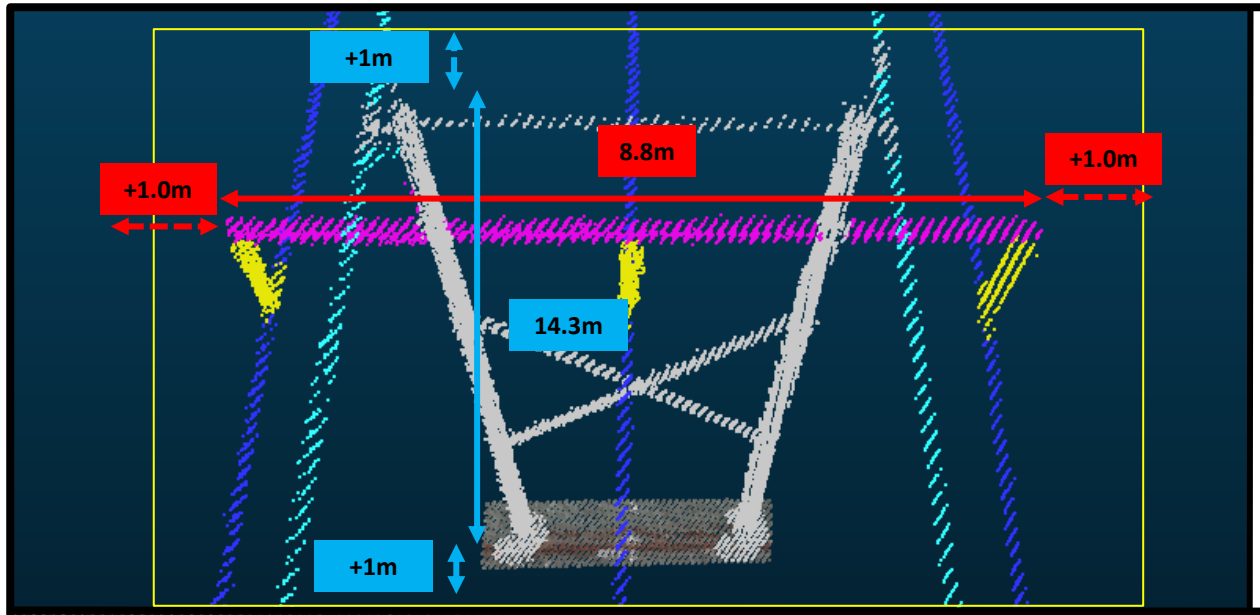
- Variable — *(x, y, z) of center of image*
- UAS at 0° azimuth in XY plane — *azimuth/yaw clockwise with respect to forward X axis)*
- Variable pitch YZ plane — *Angle up/down from horizontal (elevation/pitch)*
  - UAS above the structure and shield wires
- Spatial resolution undefined for structure overview — *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical — *What should be in focus in the field of view?*
- Verbal Description
  - Oblique offset, looking down on the structure focused on the specific connection points
- Inspection Items
  - Objects: CA, PO1, PO2, CO1, CO2, CO3, NEU1, NEU2, IN1, IN2, IN3, XB1, XB2, XBC, GL1, GL2
  - Connection Points: NEU1_CP, NEU2_CP, CO_CP1, CO_CP2, CO_CP3,

Box	Connection	Center of Frame (x,y,z)	Spatial Extent of Visible Infrastructure (X, Y, Z) (m)			Resolution
1	NEU1_CP1	(-2.36, -0.22, 1.93)	0.3	0.3	0.3	<1mm
2	NEU2_CP1	(2.30, -0.29, 2.06)	0.3	0.3	0.3	<2mm
3	CO_CP1	(-4.29, 0, -1.46)	0.5	0.5	0.5	<2mm
4	CO_CP2	(0, 0, -1.67)	0.5	0.5	0.5	<2mm
5	CO_CP3	(4.37, 0, -1.77)	0.5	0.5	0.5	<2mm
6	GL1	(-2.19, -0.52, -11.25)	1	1	1	<5mm
7	GL2	(2.13, -0.52, -11.08)	1	1	1	<5mm

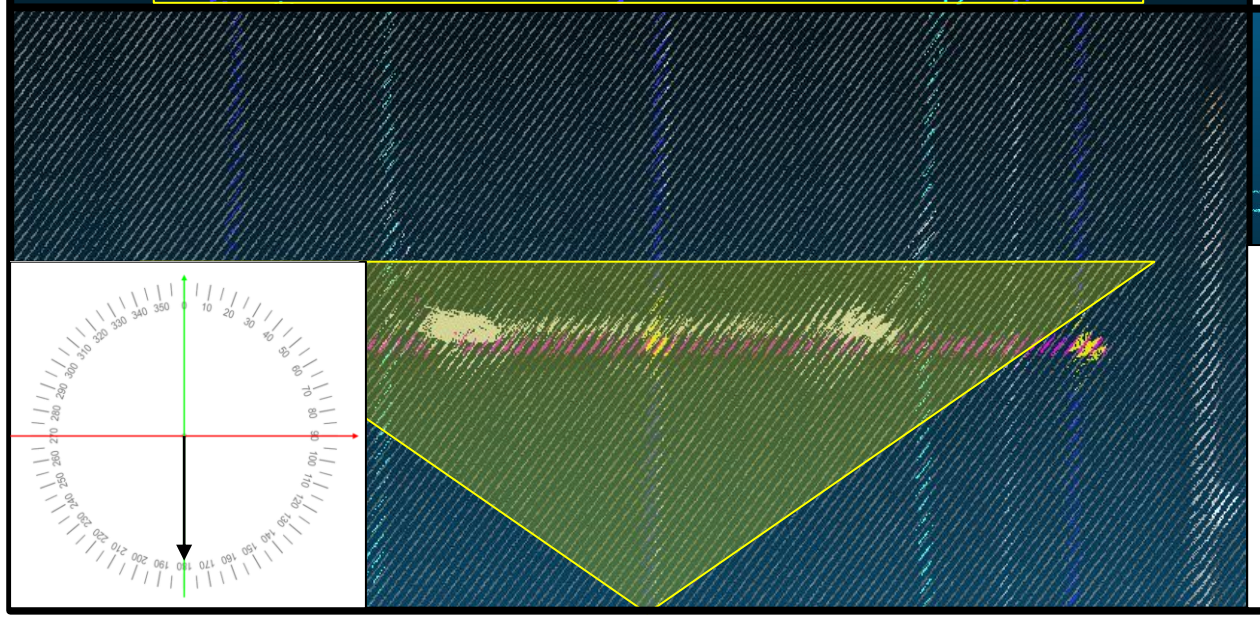


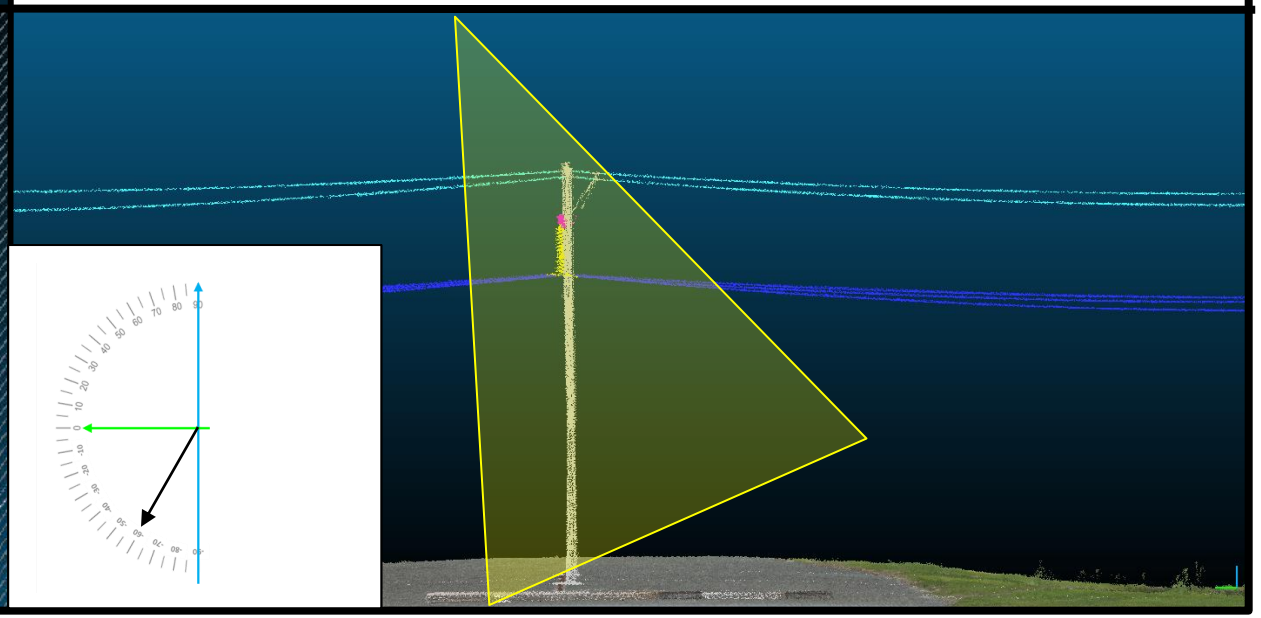
H-frame, L2B "Structure Overview, Center at mid-height, Oblique Backward"

Collective Image Total: 10

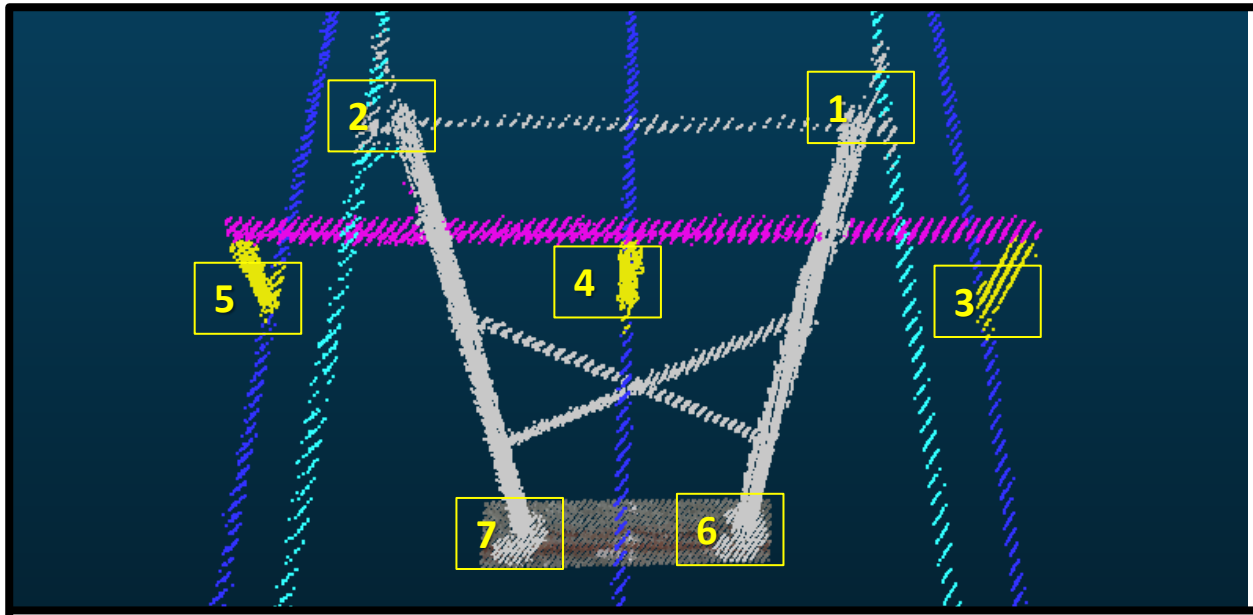


- (0,0,-5.1m) *(x, y, z) of center of image*
- 180° azimuth in XY plane *azimuth/yaw clockwise with respect to forward X axis)*
- -60° pitch YZ plane *Angle up/down from horizontal (elevation/pitch)*
- Spatial resolution undefined for structure overview *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical *What should be in focus in the field of view?*
  - >10.8m horizontal along X
  - >16.3m vertical along Z
- Verbal Description
  - Oblique offset, looking down on the structure with the entire structure in the frame (minus conductors)
- Inspection Items
  - Objects: CA, PO1, PO2, CO1, CO2, CO3, NEU1, NEU2, IN1, IN2, IN3, XB1, XB2, XBC, GL1, GL2
  - Connection Points: NEU1_CP, NEU2_CP, CO_CP1, CO_CP2, CO_CP3, XBC_CP1





H-frame, L2A "Structure Overview, Center at mid-height, Oblique Forward" Collective Image Total: 17

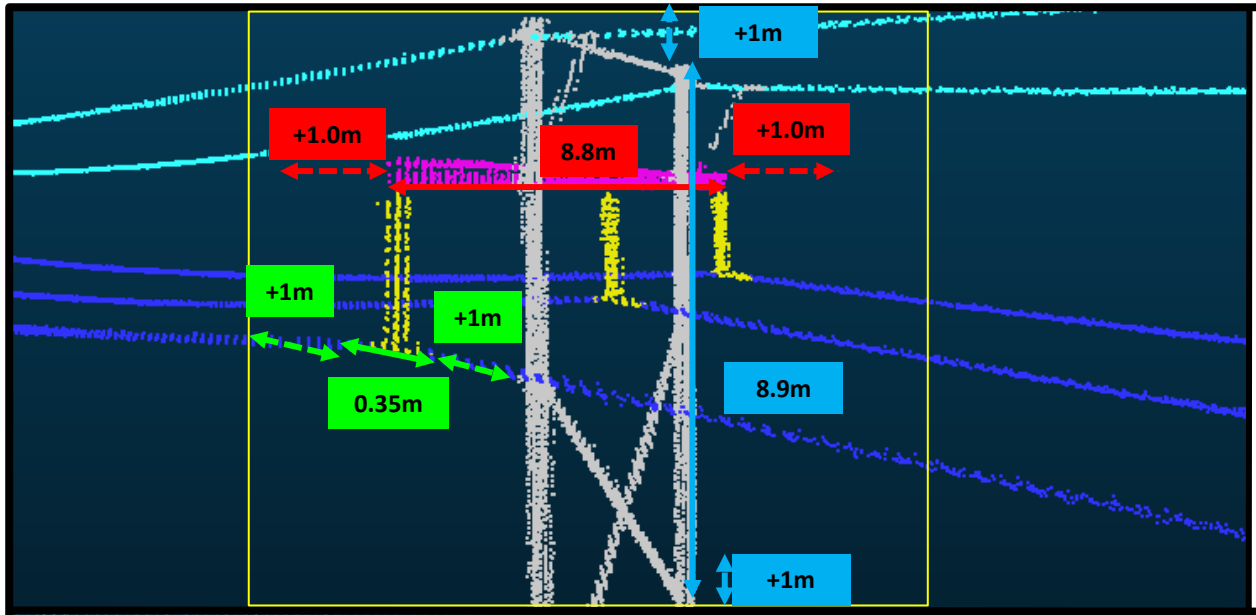


- Variable — *(x, y, z) of center of image*
- UAS at 0° azimuth in XY plane — *azimuth/yaw clockwise with respect to forward X axis)*
- Variable pitch YZ plane — *Angle up/down from horizontal (elevation/pitch)*
  - UAS above the structure and shield wires
- Spatial resolution undefined for structure overview — *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical — *What should be in focus in the field of view?*
- Verbal Description
  - Oblique offset, looking down on the structure focused on the specific connection points
- Inspection Items
  - Objects: CA, PO1, PO2, CO1, CO2, CO3, NEU1, NEU2, IN1, IN2, IN3, XB1, XB2, XBC, GL1, GL2
  - Connection Points: NEU1_CP, NEU2_CP, CO_CP1, CO_CP2, CO_CP3,

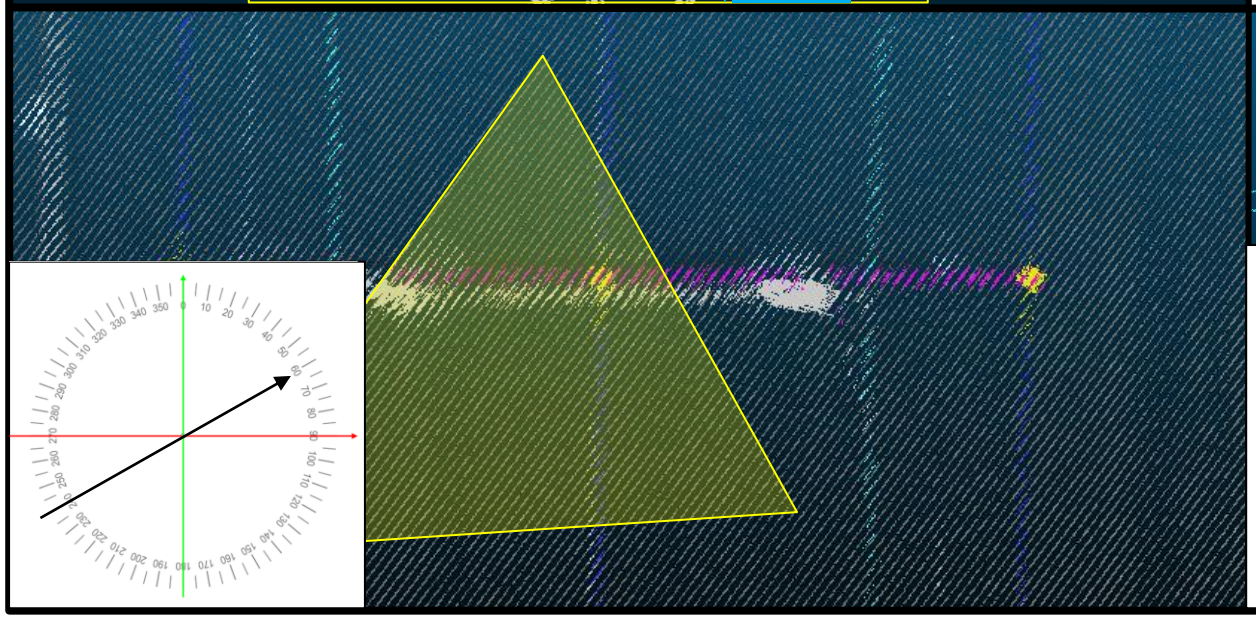
Box	Connection	Center of Frame (x,y,z)	Spatial Extent of Visible Infrastructure (X, Y, Z) (m)			Resolution
1	NEU1_CP1	(-2.36, -0.22, 1.93)	0.3	0.3	0.3	<1mm
2	NEU2_CP1	(2.30, -0.29, 2.06)	0.3	0.3	0.3	<2mm
3	CO_CP1	(-4.29, 0, -1.46)	0.5	0.5	0.5	<2mm
4	CO_CP2	(0, 0, -1.67)	0.5	0.5	0.5	<2mm
5	CO_CP3	(4.37, 0, -1.77)	0.5	0.5	0.5	<2mm
6	GL1	(-2.19, -0.52, -11.25)	1	1	1	<5mm
7	GL2	(2.13, -0.52, -11.08)	1	1	1	<5mm

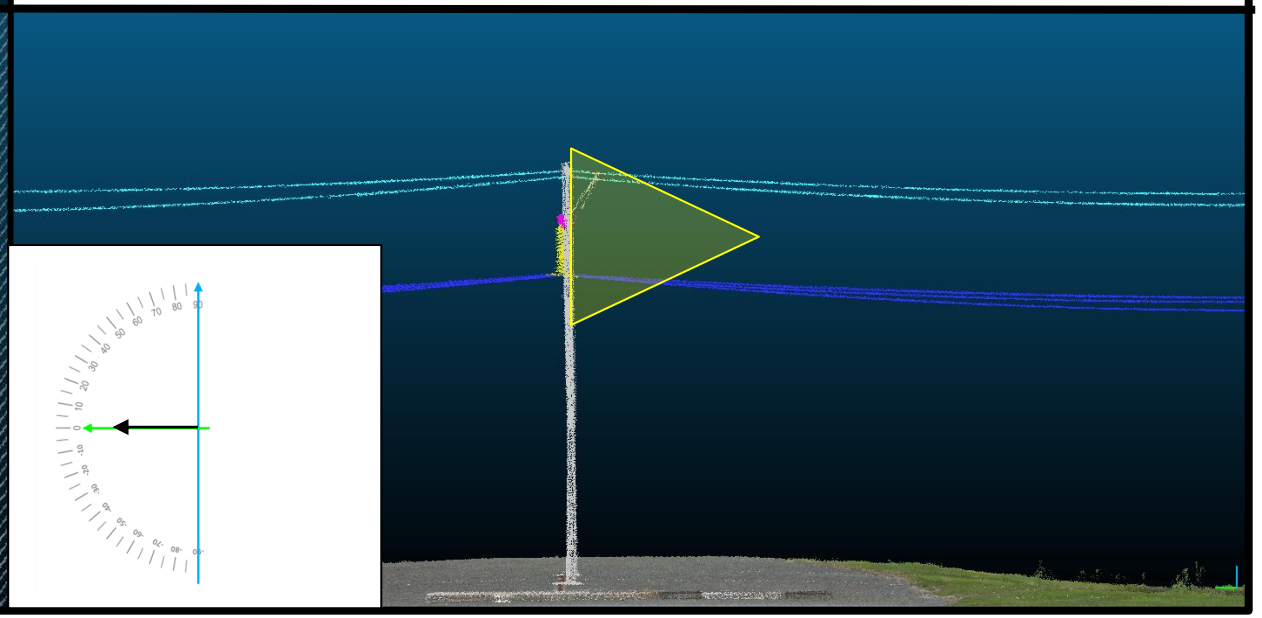
H-frame, L3A “At Height Oblique, Center at Origin, 60° Azimuth”

Collective Image Total: 18



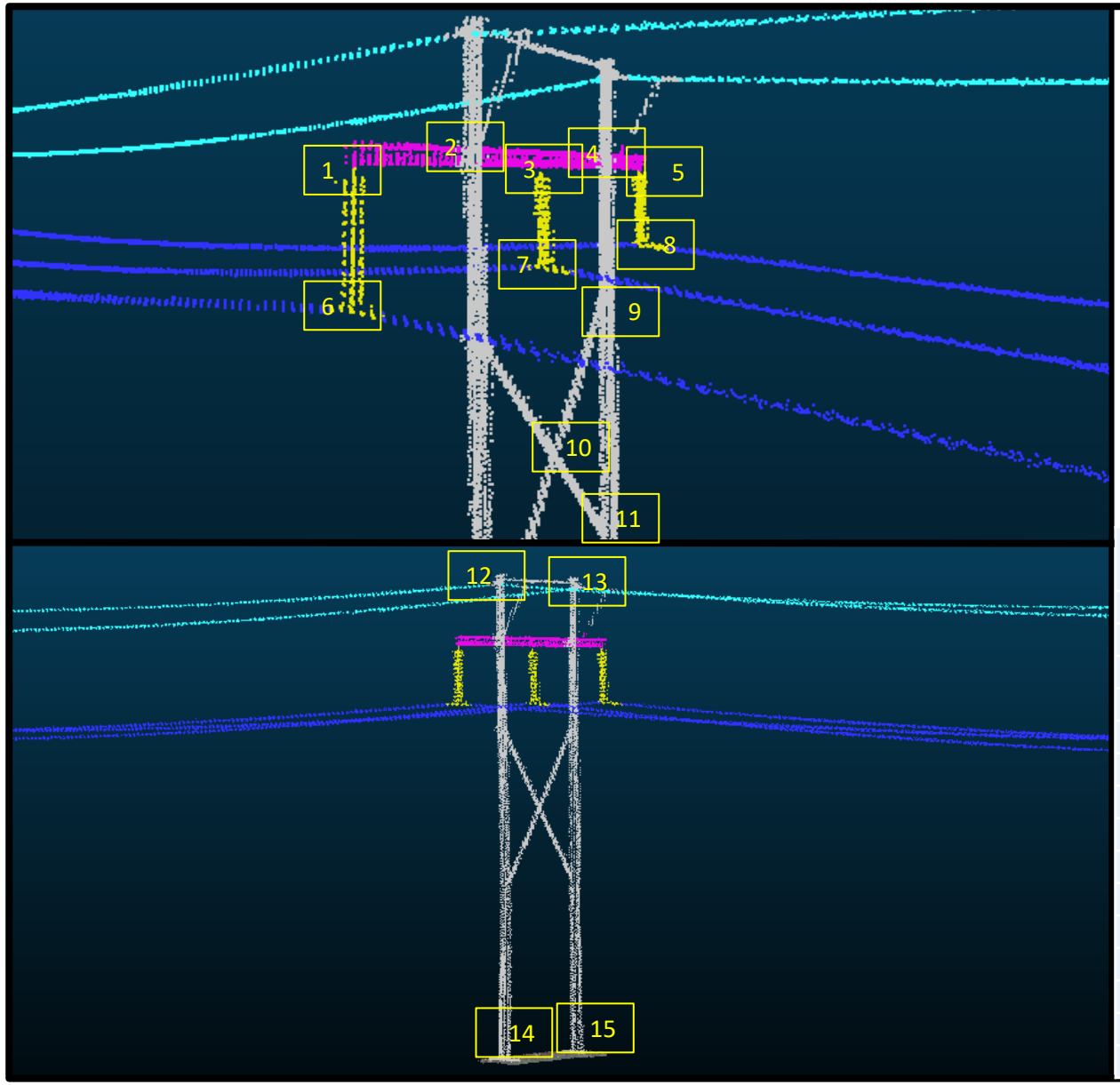
- (0,0,0) *(x, y, z) of center of image*
- 60° azimuth in XY plane *azimuth/yaw clockwise with respect to forward X axis)*
- 0° pitch YZ plane *Angle up/down from horizontal (elevation/pitch)*
- Spatial resolution undefined for structure overview *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical *What should be in focus in the field of view?*
  - >10.8m horizontal along X
  - >16.3m vertical along Z
- Verbal Description
  - Oblique offset, looking into the structure at a 60° azimuth
- Visible Components
  - NEU1, CA, IN1, IN2, IN3, PO1, PO2, CO1, CO2, CO3, XB1, XB2





H-frame, L3A “At Height Oblique, Multiple AOIs, 60° Azimuth”

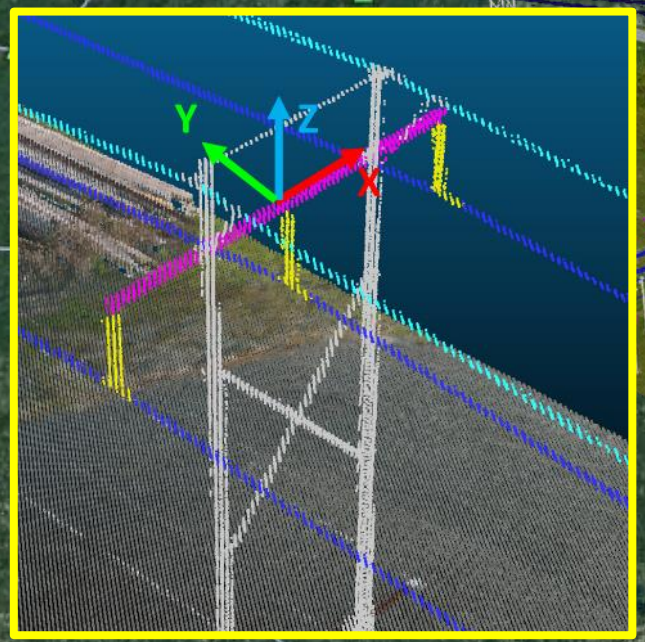
Collective Image Total: 33



- (0,0,0) *(x, y, z) of center of image*
- 60° azimuth in XY plane *azimuth/yaw clockwise with respect to forward X axis)*
- Variable pitch YZ plane *Angle up/down from horizontal (elevation/pitch)*
  - UAS height even with origin on Z-axis
- Spatial resolution defined below *Rule of Thumb: half size of smallest defect*
- Spatial extent of infrastructure horizontal or vertical *What should be in focus in the field of view?*
  - Defined below
- Verbal Description
  - Oblique offset, focusing on the structure connection points at 60° azimuth.
- Inspection Items
  - Objects: CA, PO1, PO2, CO1, CO2, CO3, NEU1, NEU2, IN1, IN2, IN3, XB1, XB2, XBC, GL1, GL2
  - Connection Points: NEU1_CP, NEU2_CP, CO_CP1, CO_CP2, CO_CP3, XBC_CP1

Box	Connection	Center of Frame (x,y,z)	Spatial Extent of Visible Infrastructure (X, Y, Z) (m)			Resolution
1	IN_CP1	(-4.36, 0, 0)	0.3	0.3	0.3	<1mm
2	CA_CP1	(-2.12, 0, 0)	0.5	0.5	0.5	<2mm
3	IN_CP2	(0, 0, 0)	0.3	0.3	0.3	<1mm
4	CA_CP2	(2.00, 0, 0)	0.5	0.5	0.5	<2mm
5	IN_CP3	(4.30, 0, 0)	0.3	0.3	0.3	<1mm
6	CO_CP1	(-4.35, 0, -1.65)	0.3	0.3	0.3	<1mm
7	CO_CP2	(0, 0, -1.70)	0.3	0.3	0.3	<1mm
8	CO_CP3	(4.35, 0, -1.76)	0.3	0.3	0.3	<1mm
9	XB2_CP2	(1.85, -0.28, -2.58)	0.5	0.5	0.5	<2mm
10	XBC_CP1	(-0.23, -0.36, -4.84)	0.5	0.5	0.5	<2mm
11	XB1_CP2	(1.86, -0.33, -6.94)	0.5	0.5	0.5	<2mm
12	NEU1_CP1	(-2.58, -0.34, 1.78)	0.3	0.3	0.3	<1mm
13	NEU2_CP1	(1.95, -0.24, 1.92)	0.3	0.3	0.3	<1mm
14	GL1	(-2.46, -0.35, -12.05)	1	1	1	<5mm
15	GL2	(2.05, -0.45, -12.16)	1	1	1	<5mm

Field Demonstrations (Training Environment) and Testing



noxville
Greensboro
S10
S7
S1
Raleigh
Roanoke Island
Pamlico Sound
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South Carolina
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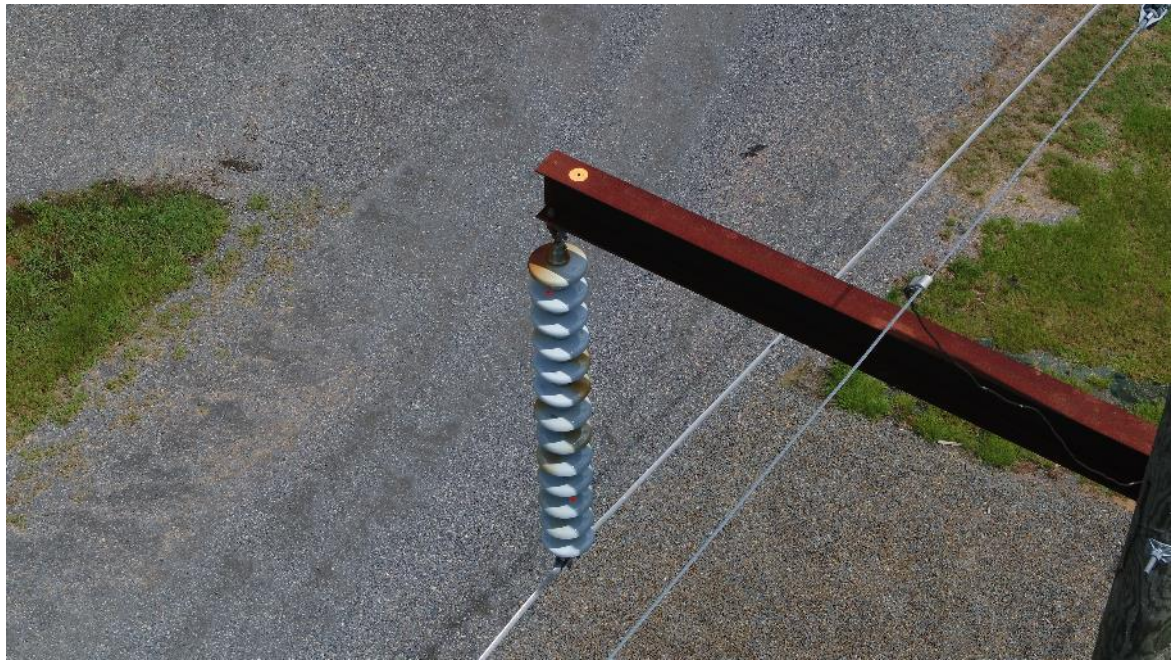
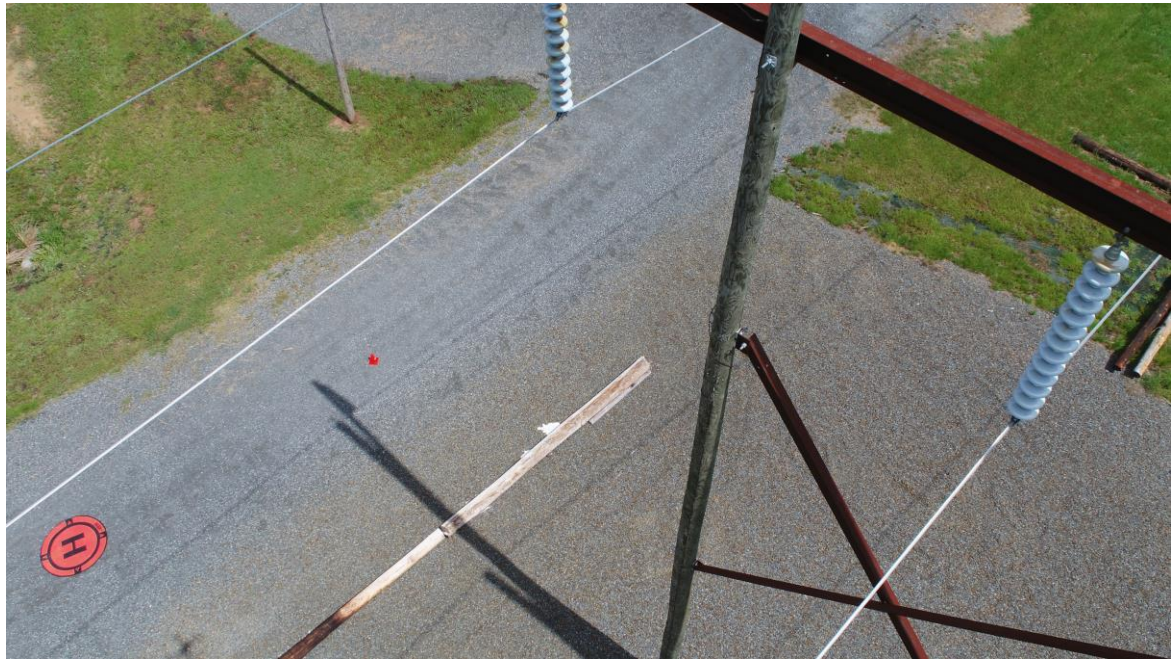
Image Landsat / Copernicus
Google Earth

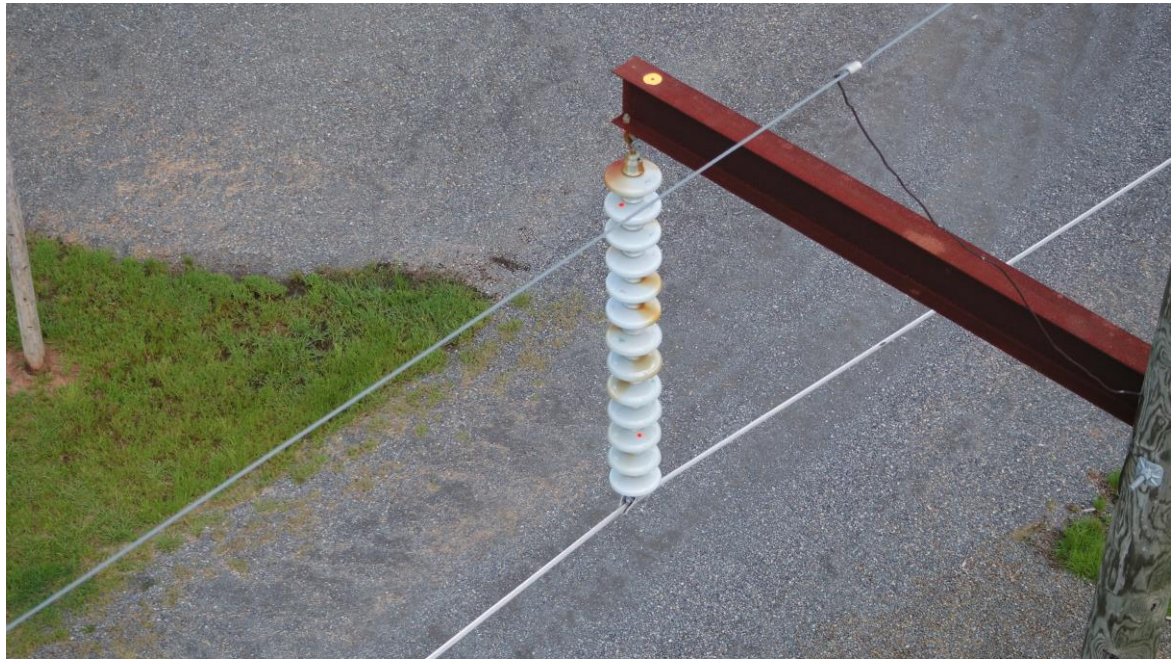
August 16 – 20, 2021


Defect Staging

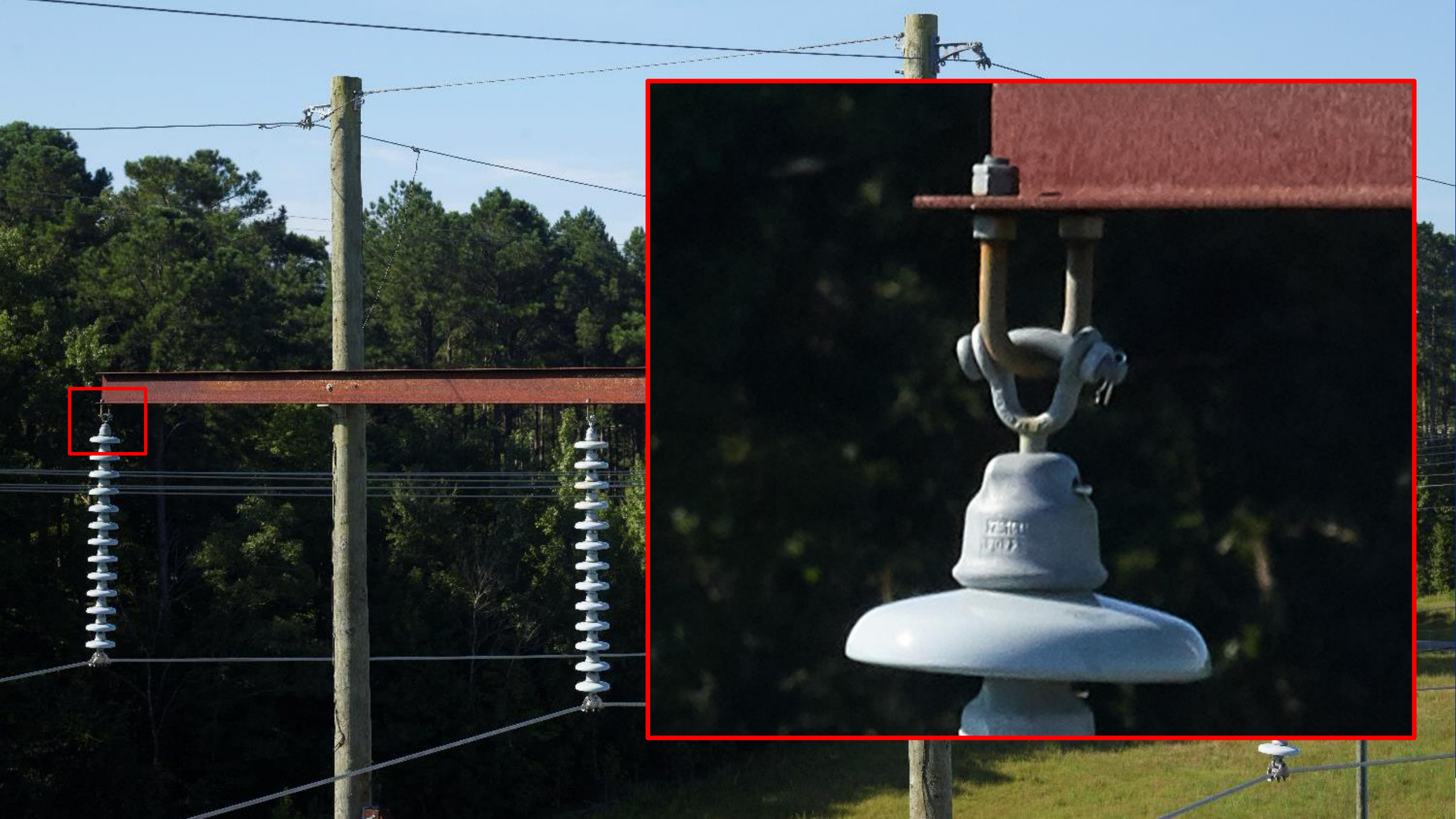
Inspector-in-the-Loop





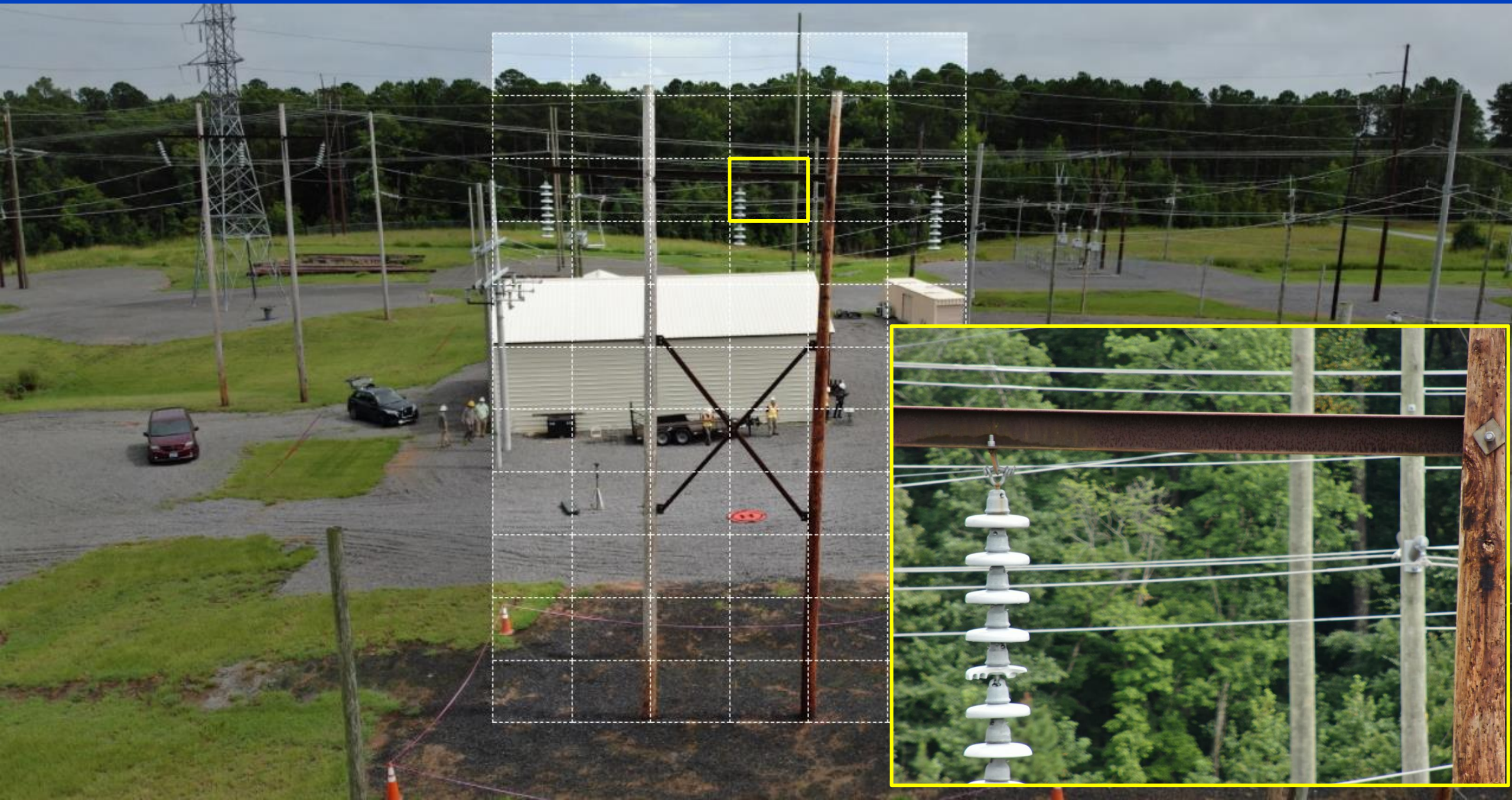


100mP Capture



Skydio – 3D Scan

DJI – Grid Capture



DJI – Smart AI Capture

DJI_20210819135446_0001_Z.JPG

DJI_20210819135523_0002_Z.JPG

DJI_20210819135538_0003_Z.JPG

DJI_20210819135615_0004_Z.JPG

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DJI_20210819141322_0003_Z.JPG

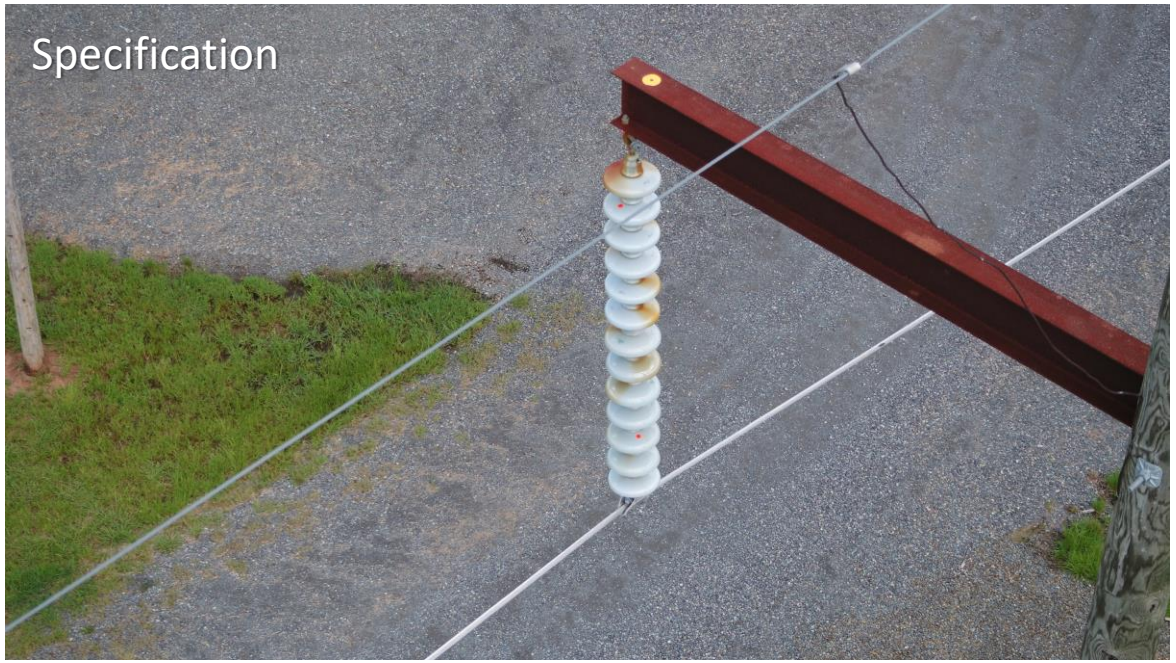
DJI_20210819141340_0004_Z.JPG

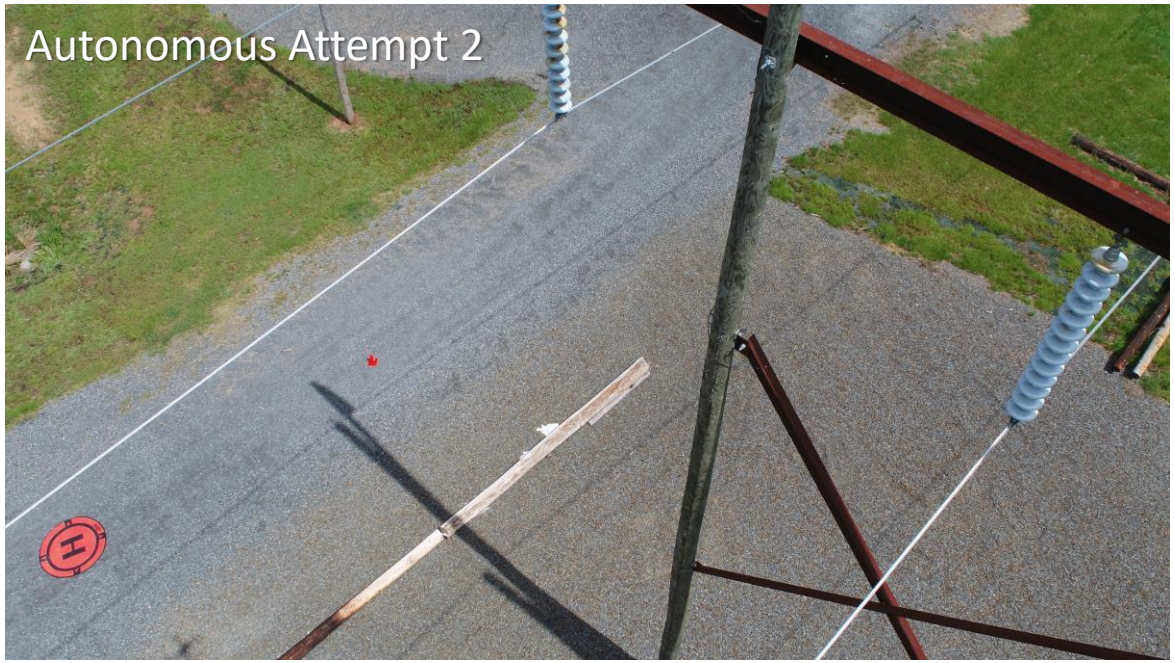
DJI_20210819141403_0005_Z.JPG

Option 1:
Getting the perfect picture.

Challenges:

1. Framing, lighting, and focus
2. LiDAR and geospatial accuracy
3. Capture consistency





Option 2:
Capture overlapping images from multiple perspectives

Challenges:

1. Data volume (transfer, review, storage)
2. Collection time
3. Optimizing the capture parameters

Z-Axis Rotations with 15° below Horizon at 5, 10, and 15ft proximity

Optimizing for inspection quality vs. quantity can be challenging.

Standoff: 5 ft
Duration: 4m
Total Images: 65
Size:454 MB

Standoff: 10 ft
Duration: 2.5m
Total Images: 27
Size:193 MB

Standoff: 15 ft
Duration: 2m
Total Images: 24
Size:171 MB

Minimal Yet Optimal Flight Planning (Upcoming Presentation)

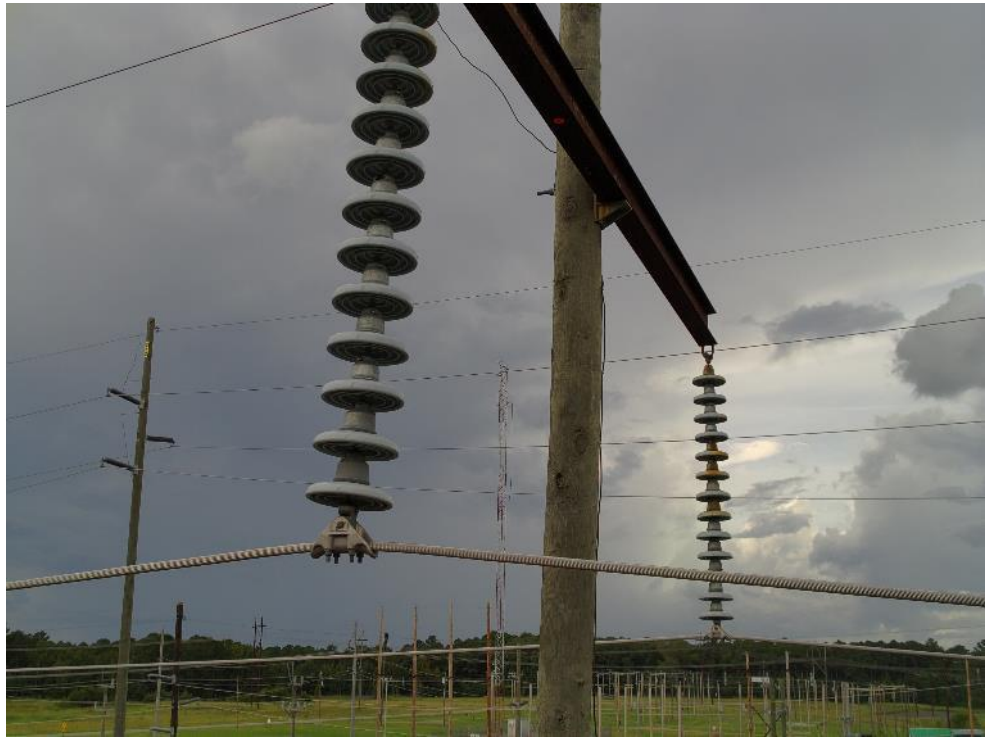
The inspection requirements determine the flight profile.

Aerial Patrols

- Quick “fly-by’s” looking for large and easily identifiable issues
- Fast, but limited perspective and resolution

Comprehensive Inspections

- “Hovering” flights looking for component failures from multiple perspectives
- Slow, but multiple perspectives and higher resolution



GPS Impairment from Vegetation (Upcoming Presentation)

Photo's courtesy of K. McCraney

What are the drone automation solutions of tomorrow?

- Utility image/video capture specifications
- Flight and Navigation
  - GPS waypoint navigation with intelligent deviation
  - Robust collision avoidance
    - Visual, LiDAR, Both?
  - Machine vision features for edge decision-making
    - conductor following
    - object detection for payload targeting
    - object detection and defect recognition

EPRI's **ongoing research** addresses today's gaps so that we can build tomorrow's solutions.

UAS Automation Technologies for Transmission Inspection *Phase 2*

Objectives and Scope

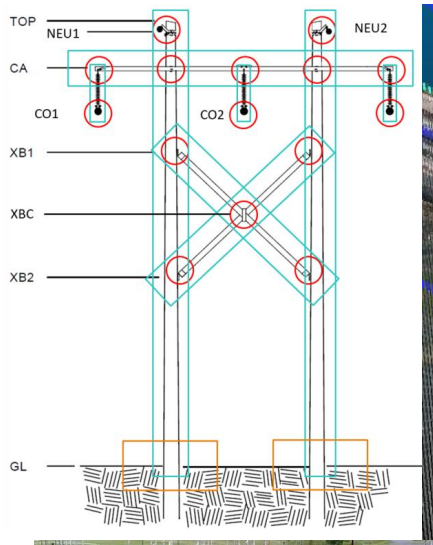
- Build on previous research to evaluate automated comprehensive transmission inspections using UAS
- Determine efficiency impact of using automation for inspection
- Compare inspection quality, speed, and cost to traditional methods

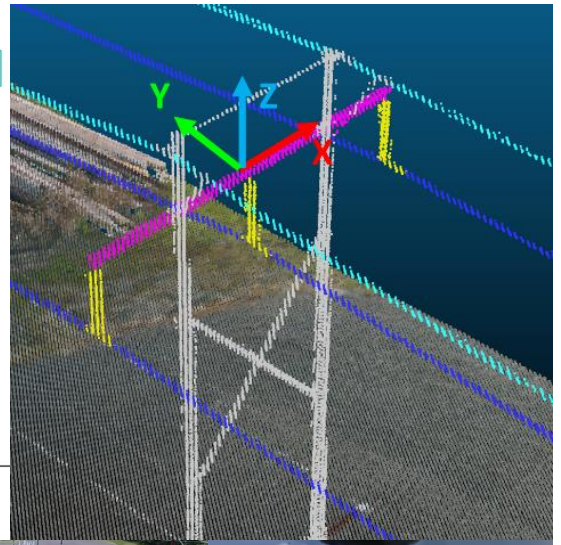
Value

- Knowledge to support implementation decisions
- Firsthand experience with an automated inspection solution
- Increased awareness of the near, mid, and long-term potential of UAS

Project Information

- Project ID: 1-112942
- Project Supplemental Number: 3002017783
- Project Manager: Dexter Lewis, dlewis@epri.com





Advanced Distribution Inspection:
Using Automation for Inspection

Objectives and Scope

- Guidance on technologies and approaches for automating distribution inspection
- Learn through lab and field experience how to collect the right inspection data
- Understand the feasibility of using automated image analysis for defect detection
- Quantify performance of AI predictions with objective processes and datasets

Value

- Experience with a new, automated inspection approach that may reduce the cost of distribution inspection
- Provide objective data to inform deployment decisions such as inspection processes, vendor selection, and purchasing decisions

Project Information

- Project ID: 1-113854
- Project Supplemental Number: 3002019622
- Project Manager: Dexter Lewis, dlewis@epri.com

Join us Thursday, Dec. 2nd 1:00 – 2:30 PM ET

UAS in the Field: Tips, Tricks, and Tools

EPRI Introduction on UAS in the Field	5 min	Dexter Lewis, EPRI
Photography Tips for Inspection	30 min	Dennis Washington, Alabama Power Company
(Panel Session) Tips, Tricks, and Tools in the Field	30 min	SkySkopes, City of Troy Utilities, Osmose
Tips during Disaster Repsone and Utility Program Management	20 min	Eric Schwartz, FPLAir
EPRI Conclusion	5 min	Dexter Lewis, EPRI

Dec. 7th 1:00 – 2:30 PM ET	Post Processing and AI
Dec. 9th 1:00 – 2:30 PM ET	T&D Specific Research
Dec. 14th 1:00 – 2:30 PM ET	Generation Specific Research
Dec. 16th 1:00 – 2:30 PM ET	New Utility UAS Applications